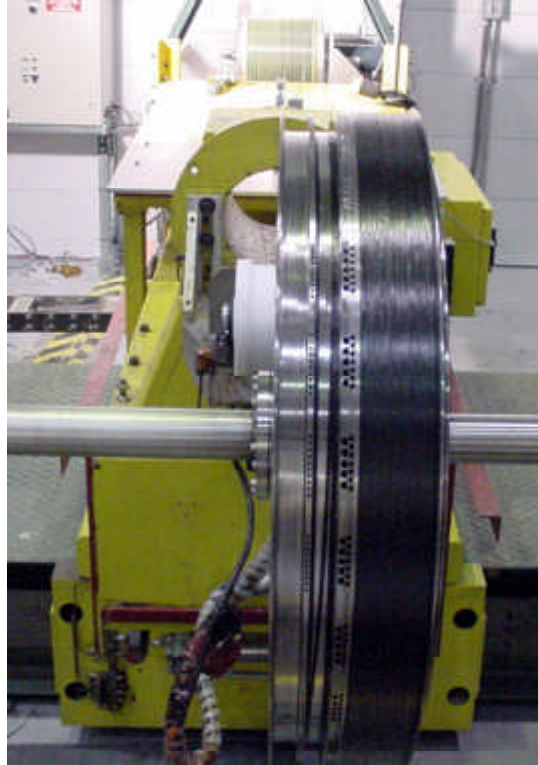


# Single-Stage, 3.4:1-Pressure-Ratio Aspirated Fan Developed and Demonstrated

Researchers are constantly pursuing technologies that will increase the performance of gas turbine engines. The aspirated compressor concept discussed here would allow the compression system to perform its task with about one-half of the compressor blades. To accomplish this, the researchers applied boundary layer control to the blades, casing, and hub. This method of boundary layer control consisted of removing small amounts of air from the main flow path at critical areas of the compressor. This bleed air could be used by other systems such as engine cooling or could be reinjected into lower pressure areas that require air for enhanced performance.





*Left: Tip shrouded aspirated rotor with bleed slots on blade surfaces and bleed holes in shroud. Right: Aspirated rotor 50-percent wound with carbon fiber/epoxy matrix. Holes in the shroud are exit paths for bleeds taken from blades and shroud.*

Long description of left figure. The aspirated rotor looks like a fan that has 26 blades, with an outer shroud, or ring, that encircles the tips of the blades. The blades are curved, and on the convex side a 1/8-in.-wide slot is cut into the blade extending radially along the outer 50 percent of the blade surface.

Between each of the blades on the outer shroud, there are eight small holes.

Long description of right figure. This is an edge-on view of the rotor as it is mounted on a shaft that can spin the rotor. As the rotor is spun at a slow speed, the carbon filament coated with epoxy fills the grooves in the shroud, much like thread being wound onto a bobbin. The picture shows one groove filled, with two adjacent grooves empty. Small holes can be seen in the metal between the grooves, these holes are the exit ports for the boundary layer bleed slots on the blades.

This effort was initiated by the Massachusetts Institute of Technology (MIT) in response to a solicitation from the Defense Advanced Research Projects Agency (DARPA) who sought to advance research in flow control technology. The NASA Glenn Research Center partnered with MIT (principal investigator), Honeywell Aircraft Engines (cycle analysis, structural analysis, and mechanical design), and Pratt & Whitney (cycle analysis and aeroanalysis) to conceptualize, design, analyze, build, and test the aspirated fan stage. The aerodesign and aeroanalysis of this fan stage were jointly executed by MIT and Glenn to minimize the amount of bleed flow needed and to maintain the highest efficiency possible (ref. 1). Mechanical design issues were complicated by the need to have a shrouded rotor with hollow blades, with rotor stress levels beyond the capabilities of titanium. The high stress issues were addressed by designing a shroud that was filament wound with a carbon fiber/epoxy matrix, resulting in an assembly that was strong enough to handle the high stresses. Both the rotor (preceding photographs) and stator (following photograph) were fabricated in two halves and then bolted together at the hub and tip, permitting the bleed

passages to be machined into each half before assembly.



*Aspirated stator with bleed slots on blade surfaces, bleed holes along the stator hub, and pitchwise bleed slot between blades.*

Long description. This is a closeup view of the aspirated stator blades. Similar to the rotor in the first photograph, there are bleed slots on the convex surface of the blades extending from hub to tip, with small holes on the hub at the intersection of the blade and the hub. These holes begin about 1 inch from the front edge of the blade, and they continue to the back edge of the blade. About 1 inch back from the front edge of the blades, slots can be seen on the hub that extend from blade to blade.

The aspirated fan stage was successfully tested at Glenn in December 2002 from 0 to 100 percent of the design speed and from 0 to 100 percent of the design mass flow rate. The stage pressure ratios and mass flow rates agreed very well with the pretest predicted values obtained from an in-house turbomachinery flow analysis code. This is a significant accomplishment given the complexity involved in the aerodynamic design of the blading and suction slot placements. The fan stage delivered a pressure ratio 50-percent higher than for conventional designs operating at the same speeds. This effort validates both the aerodesign and aeroanalysis codes used in this project. The aerodesign code known as MISES was developed by MIT, and the aeroanalysis code applied was APNASA, a Glenn in-house-developed code. Research in this area continues by NASA, academia, and industry.

## Reference

1. Merchant, A.A., et al.: Aerodynamic Design and Analysis of a High Pressure Ratio Aspirated Compressor Stage. ASME Paper 2000-GT-619, 2000.

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